The Royal Veterinary and Agricultural University
Food and Resource Economic Institute

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Unit of Economics Working Papers 1999/6

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January 1999

Abstract

We consider how to organize the processing and marketing of an agricultural product when farming costs are known only by the individual farmers. We show that when marginal costs are un-correlated and the market for final goods is competitive, the socially optimal production levels may be sustained by a cooperative and a cooperative only. We show also that the cooperative form is particularly useful when the uncertainty is large and the net revenue product is small.

Keywords: Economics of Cooperatives, Asymmetric Information, Incentives.

1 Introduction

A cooperative's primary trading partners are the members which are also the residual claimants. This suggests that a cooperative may have comparative advantages in terms of incentive compatibility.

Staatz(1984) among others have argued that the risk of post-harvest 'hold-ups' is a primary reason for cooperatives active presence in the marketing of short lived products like fruits, vegetables and milk. On the other hand, it is well known also that ordinary hold-up problems can be handled effectively by using long term contracts, cf. e.g. Tirole(1988). By negotiating the transaction terms before production decisions are made, i.e. by using ex-ante rather than ex-post negotiations, the production costs will be honored and the producers will not be forced to under-produce. Hence, the traditional hold up problem is solved by a cooperative - but not only by a cooperative.

The aim of this paper is to show that certain incentive problems can be handled effectively using a cooperative - and a cooperative only. We suggest an economic rationale for cooperatives by providing a framework where a cooperative is the unique optimal organization form.

The idea is simple. If farmers have private information about their production costs, ex-ante negotiations may not be efficient. The more efficient farmers will try to extract informational rents by imitating the less efficient ones. The rational response of a buyer is to reduce transactions below the first best level. This leads to an ex post in-efficient situation. As we shall show, the only way to eliminate the associated economic loss is to have the farmers integrate forward, i.e. take over the processing, and to do so on a cooperative basis where the processing surplus is shared among farmers in proportion to patronage.

The outline of the paper is as follows. We first present the set-up and a useful reformulation of the incentive compatibility constraints. In Section 3, we characterize the socially optimal production structure and the profit sharing principles that may support it. The similarities with cooperative processing is explored in Section 4, and the effects of investor owned processing is investigated in Section 5. Some examples are given in Section 6, extensions are discussed in Section 7, and conclusions are given in Section 8.

2 The Model

We consider n farmers producing the same (homogenous) product. For farmer $i \in I = \{1, ..., n\}$, we let q_i be his production level, $C_i(q_i) := c_i \cdot q_i$ his production costs and q_i^U his capacity. The farmers maximize expected profit.

We assume that information about production costs are asymmetric and incomplete. The marginal cost c_i at farmer i is known by him only. The other farmers as well as the processor only hold beliefs about his cost. Specifically, we assume that the costs are independent and that c_i 's density $f_i(c_i)$ =

$\partial F_i(c_i)/\partial c_i$ has support $C_i = [c_i^L, c_i^U]$. As a matter of notation, we let $c = (c_i)_{i\in I}, c_{-i} = (c_j)_{j\neq i}, C = \times_{i\in I} C_i$, and $C_{-i} = \times_{j\neq i} C_j$.

The farm output is processed and the processed product is sold at a market. We assume that one unit of farm output leads to one unit of processed product and that the market price of the processed product net of processing costs is constant and equal to p. In the terminology from the economics of cooperatives, p is the constant Net Average Revenue Product (NARP).

There are many possibilities to organize processing. Different owner-ship structures are possible, price and quantity negotiations may be organized in different ways, production rights may be allocated using different auction mechanisms, and profits may be shared using a variety of sharing rules to name just a few of the design variables available. Fortunately, by the revelations principle, see e.g. Myerson(1979), we know that whatever can be accomplished by a given organization can be accomplished also in a direct revelation game in which the individual farmers have incentives to honestly reveal their private costs and where production and compensation levels are allowed to depend on the cost types reported. Therefore, letting

$$\begin{array}{l} q_i(.) : C \longrightarrow [0, q_i^U] \\ s_i(.) : C \longrightarrow \Re_0 \end{array}$$

be the production and compensation plan for farmer i, $i \in I$, we can formulate the organizational design problem as one of designing production and payment schemes $q(.) = (q_i(.))_{i\in I}$ and $s(.) = (s_i(.))_{i\in I}$ to solve **(P)**

$$\begin{array}{llcll}
\max\limits_{q(c),s(c)} & G(q,s) & & & \\
\text{s.t.} & E_{c_{-i}}^{c_i}\left(s_i(c) - c_i \cdot q_i(c)\right) & \geq & 0 & \forall c_i, i \\
& E_{c_{-i}}^{c_i}\left(s_i(c) - c_i \cdot q_i(c)\right) & \geq & E_{c_{-i}}^{c_i}\left(s_i(c_i', c_{-i}) - c_i \cdot q_i(c_i', c_{-i})\right) & \forall c_i, c_i', i \\
& \sum_{i=1}^n s_i(c) & \leq & \sum_{i=1}^n p \cdot q_i(c) & \forall c \\
& 0 \leq q_i(c) \leq q_i^U & & & \forall c, i
\end{array}$$

where $E_{c_{-i}}^{c_i}(.)$ is the conditional expectation with respect to c_{-i} given c_i. The objective function of the design program is arbitrary at this point. The first set of constrains are the individual rationality (IR) constraints. They ensure that all farmers get at least their reservation utility, arbitrarily normed to be 0. The second set of constraint are the incentive compatibility (IC) constraints. They ensure that all farmers will reveal their true types. The third set of constraints are the budget balancing (BC) constraints. They say that the farmers can not get more than what is earned at the market place.[1]

The incentive compatibility constraints induce considerable structure on the production and payment plans. For an arbitrary production and payment scheme for farmer i, $q_i(c)$ and $s_i(c)$, let $\bar{q}_i(c_i)$ and $\bar{s}_i(c_i)$ be the corresponding conditional expected production and payment when the types of the other farmers have been integrated out, i.e.

$$\begin{aligned} \bar{q}_i(c_i) &:= E^{c_i}_{c_{-i}}\left(q_i(c_i, c_{-i})\right) \quad \forall c_i \\ \bar{s}_i(c_i) &:= E^{c_i}_{c_{-i}}\left(s_i(c_i, c_{-i})\right) \quad \forall c_i \end{aligned}$$

We now have the following useful proposition.

Proposition 1 *The production and payment schemes $q(.) = (q_i(.))_{i \in I}$ and $s(.) = (s_i(.))_{i \in I}$ are incentive compatible if and only if*

- $c_i' > c_i'' \Rightarrow \bar{q}_i(c_i') \leq \bar{q}_i(c_i'') \ \ \forall i, c_i', c_i''$, and
- $\bar{s}_i(c_i) = k_i + c_i \cdot \bar{q}_i(c_i) + \int_{c_i}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i \ \ \forall i, c_i$

Proof. Initially, we note that by independence, the conditional expectation operator $E^{c_i}_{c_{-i}}(.)$ does not depend on the specific value of the costs c_i. Therefore, the incentive compatibility constraints are equivalent to

$$\bar{s}_i(c_i) - c_i \cdot \bar{q}_i(c_i) \geq \bar{s}_i(c_i') - c_i \cdot \bar{q}_i(c_i') \ \ \forall i, c_i, c_i'. \qquad (1)$$

To show the two properties in the proposition, we consider a given i and note that (1) for arbitrary c_i' and c_i'' with $c_i' > c_i''$implies

$$\begin{aligned} \bar{s}_i(c_i') - c_i' \cdot \bar{q}_i(c_i') \geq \bar{s}_i(c_i'') - c_i' \cdot \bar{q}_i(c_i'') = \bar{s}_i(c_i'') - c_i'' \cdot \bar{q}_i(c_i'') + (c_i'' - c_i')\bar{q}_i(c_i'') \\ \bar{s}_i(c_i'') - c_i'' \cdot \bar{q}_i(c_i'') \geq \bar{s}_i(c_i') - c_i'' \cdot \bar{q}_i(c_i') = \bar{s}_i(c_i') - c_i' \cdot \bar{q}_i(c_i') + (c_i' - c_i'')\bar{q}_i(c_i') \end{aligned}$$

or equivalently

$$-\bar{q}_i(c_i'') \leq \frac{\bar{s}_i(c_i') - c_i' \cdot \bar{q}_i(c_i') - (\bar{s}_i(c_i'') - c_i'' \cdot \bar{q}_i(c_i''))}{c_i' - c_i''} \leq -\bar{q}_i(c_i') \qquad (2)$$

[1]We assume that the incentive problem is related to the cost types only. The planned production levels can be implemented without additional incentive problems eg because the chosen production levels are directly verifiable such that deviations can be avoided with infinitely harsh punishment treats. We therefore do not need to let $s_i(.)$ depend on the actual production levels.

In particular, $c_i' > c_i'' \Rightarrow \bar{q}_i(c_i') \leq \bar{q}_i(c_i'')$, as claimed in the proposition. By $\bar{q}_i(\cdot)$ monotonously decreasing, it follows also that $d\bar{q}_i(c_i')/dc_i'$ exists almost everywhere (a.e.), cf. Laffont and Tirole(1993) p. 63.

Rewriting (2), we get that for all c_i' and c_i'' with $c_i' > c_i''$

$$-(c_i' - c_i'')\bar{q}_i(c_i'') \leq \bar{s}_i(c_i') - \bar{s}_i(c_i'') + c_i'' \cdot \bar{q}_i(c_i'') - c_i' \cdot \bar{q}_i(c_i') \leq -(c_i' - c_i'')\bar{q}_i(c_i')$$

or equivalently

$$\frac{c_i'(\bar{q}_i(c_i') - \bar{q}_i(c_i''))}{c_i' - c_i''} \leq \frac{\bar{s}_i(c_i') - \bar{s}_i(c_i'')}{c_i' - c_i''} \leq \frac{c_i''(\bar{q}_i(c_i') - \bar{q}_i(c_i''))}{c_i' - c_i''}$$

We see therefore that since $d\bar{q}_i(c_i')/dc_i'$ exists (a.e.), so does $d\bar{s}_i(c_i')/dc_i'$. Furthermore, going to the limit $(c_i'' \to c_i')$ in (2), we get that

$$\frac{d\left(\bar{s}_i(c_i) - c_i \cdot \bar{q}_i(c_i)\right)}{dc_i} = -\bar{q}_i(c_i) \leq 0 \qquad \text{a.e.}$$

This shows that the less efficient types earn less profit and it implies

$$\bar{s}_i(c_i) = k_i + c_i \cdot \bar{q}_i(c_i) + \int_{c_i}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i$$

which is the last property in the proposition.

We shall now show that the two properties in Proposition 1 implies incentive compatibility. Inserting the expression for $\bar{s}_i(.)$ into the incentive compatibility constraint (1) we get

$$k_i + c_i \cdot \bar{q}_i(c_i) \quad + \quad \int_{c_i}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i - c_i \cdot \bar{q}_i(c_i) \geq$$

$$k_i \quad + \quad c_i' \cdot \bar{q}_i(c_i') + \int_{c_i'}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i - c_i \cdot \bar{q}_i(c_i') \quad \forall i, c_i, c_i'.$$

Reducing and rewriting, we get

$$\int_{c_i}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i \geq \int_{c_i}^{c_i'} \bar{q}_i(c_i')\, d\tilde{c}_i + \int_{c_i'}^{c_i^U} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i \;\; \forall i, c_i, c_i'$$

which holds because $\bar{q}_i(.)$ is weakly decreasing. ■

According to Proposition 1, the less efficient types produce less. Also, the expected payment is - up to an integration constant - determined entirely from the production scheme. Proposition 1 makes it easy to analyze alternative organizations as we shall see below.

3 Central Planner's Solution

We first characterize the set of production and payment plans that are socially optimal. We shall talk about this as a central planner's solution. What defines the central planner (CP) is his objective - his aim is to maximize the market value minus the production costs of all farmers, i.e. the integrated profit from production and processing

$$G^{CP}(q,s) = \sum_{i=1}^{n} E_c\left((p - c_i) \cdot q_i(c)\right) = \sum_{i=1}^{n} E_{c_i}\left((p - c_i) \cdot \bar{q}_i(c_i)\right)$$

The central planner is assumed to have no more information about the costs of any farmer than does the other farmers or an investor-owned processor. Therefore the general design problem from Section 2 is still relevant.

We see that the central planner's objective - as the constraints - depends only on average production and payments. Also, the objective as the constraints are effectively separable in n farmer specific problems.

To maximize the net benefits from production and processing, the central planner would like to implement the following production plan

$$\bar{q}_i^{CP}(c_i) = \begin{cases} q_i^U & \text{if } c_i \le p \\ 0 & \text{otherwise} \end{cases} \qquad \forall i$$

Note that for the average production to be either the minimal or the maximal, 0 or q_i^U,the specific production level for all possible cost values must be either 0 or q_i^U,i.e. $q_i^{CP}(c) = \bar{q}_i^{CP}(c_i) \quad \forall i, c$. This plan is the first best plan, i.e. the optimal production plan with perfect cost information.

To show that this ideal solution is actually feasible, we must specify the payment plan that make the production-payment plan satisfy the IR, IC and BB constraints. However, this is easy. Using Proposition 1, we know that to be incentive compatible, the expected payment must satisfy

$$\begin{aligned} \bar{s}_i^{CP}(c_i) &= k_i + c_i \cdot \bar{q}_i^{CP}(c_i) + \int_{c_i}^{c_i^U} \bar{q}_i^{CP}(\tilde{c}_i)\, d\tilde{c}_i \\ &= \begin{cases} k_i + p \cdot q_i^U & \text{if } c_i \le p \le c_i^U \\ k_i + c_i^U \cdot q_i^U & \text{if } c_i \le c_i^U \le p \\ k_i & \text{otherwise} \end{cases} \qquad \forall i \end{aligned} \tag{3}$$

To be individually rational, we furthermore need $k_i \ge 0$.

Let us consider now the case where $p \leq c_i^U \; \forall i$. This is the casé where the informational asymmetry is non-trivial - it is not common knowledge a priori what the socially optimal production levels are. We can say also that this represents a not too profitable market condition - the net average revenue product p is not make it optimal to have all farmer types produce. From (3), we get $\bar{s}_i^{CP}(c_i) = k_i + p \cdot q_i^U \; \forall i$. Using the budget balancing constraint, the payment can be pined down even further. To fulfill BB, we need $k_i = 0 \; \forall i$. This conclusion is summarized in Proposition 2.

Proposition 2 *When $p \leq c_i^U \; \forall i$ the socially optimal (and first best) production levels can be implemented if and only if the cost dependent payments satisfy*

$$\bar{s}_i(c_i) = \begin{cases} p \cdot q_i^U & \text{if } c_i \leq p \\ 0 & \text{otherwise} \end{cases} \qquad \forall i$$

The solution in Proposition 1 is strikingly simple. It effectively sends the market signals directly to the farmers. One way to implement this market oriented solution is to ignore the communication procedure of the revelation game and offer the farmers to buy whatever they produce at the price p per unit. As we shall emphasize below, this is also the cooperative solution. Note that by the risk-neutrality of the farmers, the optimal payment schemes can only be characterized in expected terms. The payment plan is defined modula zero mean lotteries.

If $p > c_i^U$ for one or more farmers, the above payment plan still works. However, in this case, there are alternative arrangements, including some which would result in a non-allocated surplus, e.g. a strictly positive profit to a processor. The possible solutions in this case are all those with the structure given in (3) and constants $k_i, i \in I$ satisfying

$$\sum_{i \in I} k_i \leq \sum_{j: p > c_j^U} (p - c_j^U) q_j^U \tag{4}$$

The inequality (4) puts some constraint on the way the surplus can be allocated to the farmers and the processor. It leaves a surplus $\sum_{j:p>c_j^U}(p - c_j^U)q_j^U - \sum_{i \in I} k_i$ to the non-farmers, e.g. the processor or the government. We record this as a proposition as well.

Proposition 3 *When $p > c_i^U$, the socially optimal (and first best) production levels can be implemented if and only if the expected cost dependent payments satisfy (3) and (4).*

The market oriented solution from Proposition 2 is not only attractive by being simple and being the only solution that will work irrespectively of the relationship between p and c_i^U. It is also attractive from a point of view of treating all farmers equally. Moreover, the equity property implies that the mechanism is not vulnerable to side trading - no group of farmers can profit from trading the product among themselves before it is processed.

4 Cooperative Processor

There are some obvious links between the central planner's solutions in the last section and the cooperative arrangements that have be used so extensively, in particular within agriculture.

Image that processing is undertaken by a cooperative. The cooperative is owned and operated by the farmers. Assume furthermore that this is a traditional cooperative in which

1. Equity gets no interest,

2. Surplus is allocated to members in proportion to patronage,

3. Members have a right to deliver total production to the cooperative

Using the first two principles, we see that the total surplus $p\sum_{j\in I} q_j$ must be allocated as

$$s_i(c) = p[\sum_{j\in I} q_j(c_j)]\frac{q_i(c_i)}{\sum_{j\in I} q_j(c_j)}$$

In this payment plan, we have taken into account the fact that any farmer j only knows his own costs c_j and that his production decision therefore can only depend on c_j. By the farmers being risk neutral and by using the third principle above, we get that farmer i will choose $q_i(c_i)$ to solve

$$\max_{q_i} E_{c_{-i}}[p[\sum_{j\in I} q_j(c_j)]\frac{q_i(c_i)}{\sum_{j\in I} q_j(c_j)} - c_i \cdot q_i(c_i)]$$
$$\text{s.t. } 0 \le q_i(c_i) \le q_i^U$$

The cooperative (CO) solution will therefore be

$$q_i^{CO}(c_i) = \begin{cases} q_i^U & \text{if } c_i \le p \\ 0 & \text{otherwise} \end{cases} \qquad s_i^{CO}(c_i) = \begin{cases} p \cdot q_i^U & \text{if } c_i \le p \\ 0 & \text{otherwise} \end{cases} \qquad \forall i$$

i.e. the cooperative leads to the socially optimal solution from the last section.

One interpretation of Proposition 2 is therefore that *in a not too profitable market, i.e. when $p \le c_i^U$ $\forall i$, the socially optimal production levels are implementable if and only if the surplus is shared as in a cooperative modula zero mean lotteries.* This provides an information economic rationale for cooperatives. Cooperatives not only suffices to give the socially optimal production levels. Except for zero mean lotteries, cooperative sharing of the net revenue product is necessary also to ensure optimality. In any other organization, the farmers' attempts to extract informational rents will lead to a loss of desirable production. Note that contrary to the traditional under-production or under-investment problem resulting from a hold-up possibility under perfect information, cf. the Introduction, the present potential under-production problem cannot be handled by a-priori negotiation of the contracts. Long or short contracts, any attempt to divert any of the surplus from the farmers - or any attempt to share the surplus in any other way than proportional to patronage - will lead to sub-optimal production.

In a more profitable market, i.e. when $p > c_i^U$, the cooperative still leads to the social optimum. But there are other possibilities as emphasized by Proposition 3. There is some room for a paying the processor non-zero profit - or for paying a non-zero interest on the cooperative equity. There is also some room for payments that are not proportional to partronage. The room for variations which do not eliminate the social optimality of cooperative-like arrangements is given by $\sum_{j:p>c_j^U}(p - c_j^U)q_j^U$, c.f.(4).

5 Investor Owned Processor

Let us assume now that the processor is an investor owned, risk neutral profit maximizing monopsonist. Being a monopsonist, we assume that the processor has all the bargaining power. Specifically, he is able to offer contracts on a take it or leave it basis and to commit to these contracts as information is revealed.

The investor owned (IO) monopsonist's contract design problem can therefore be formulated as the general problem **(P)** with the following more specific objective

$$G^{IO}(q,s) = \sum_{i=1}^{n} E_c\left(p \cdot q_i(c) - s_i(c)\right) = \sum_{i=1}^{n} E_{c_i}\left(p \cdot \bar{q}_i(c_i) - \bar{s}_i(c_i)\right)$$

We see that the processor's objective - as the constraints - depends only on average production and payments. Also, the objective - as the constraints - are effectively separable in farmer specific problems.

Using Proposition 1, we shall now characterize the solution to this problem. Assume that $(s(.), q(.))$ is a feasible solution and let $\hat{c}_i = \sup\{c_i | \bar{q}_i(c_i) > 0\}$. By the first property in Proposition 1, $\bar{q}_i(c_i) > 0$ for all $c_i < \hat{c}_i$ and $\bar{q}_i(c_i) = 0$ for all $c_i > \hat{c}_i$. Also, it follows from the monopsonist interest in reducing payment that $\bar{s}_i(\hat{c}_i) - \hat{c}_i \cdot \bar{q}_i(\hat{c}_i) = 0$.[2] Using the second property in Proposition 1, we therefore have

$$\bar{s}_i(c_i) = c_i \cdot \bar{q}_i(c_i) + \int_{c_i}^{\hat{c}_i} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i \quad \forall c_i, i$$

Substituting this into the objective function and using partial integration, we get

$$\begin{aligned} G^{IO}(q,s) &= \sum_{i=1}^{n} \int_{c_i^L}^{\hat{c}_i} \left(p \cdot \bar{q}_i(c_i) - c_i \cdot \bar{q}_i(c_i) - \int_{c_i}^{\hat{c}_i} \bar{q}_i(\tilde{c}_i)\, d\tilde{c}_i\right) f_i(c_i)\, dc_i \\ &= \sum_{i=1}^{n} \int_{c_i^L}^{\hat{c}_i} \left[(p - c_i)\bar{q}_i(c_i) f_i(c_i) - F_i(c_i)\bar{q}_i(c_i)\right] dc_i \end{aligned}$$

This objective must be maximized subject to the constraints that production levels are weakly decreasing, i.e. $\forall i, c_i', c_i'' : c_i' > c_i'' \Rightarrow \bar{q}_i(c_i') \leq \bar{q}_i(c_i'')$, and that they do not exceed the capacities, i.e. $\forall i, c_i : 0 \leq \bar{q}_i(c_i) \leq q_i^U$.

This is easy, however, if we inwoke a bit of regularity on the cost distributions. Specifically, we will assume that the cost distributions have weakly *increasing hazard rate*, i.e. $F_i(c_i)/f_i(c_i)$ is weakly increasing on $[c_i^L, c_i^U]$ for

[2] By IR $\bar{s}_i(\hat{c}_i) - \hat{c}_i \cdot \bar{q}_i(\hat{c}_i) \geq 0$. Now if $\bar{s}_i(\hat{c}_i) - \hat{c}_i \cdot \bar{q}_i(\hat{c}_i) = \varepsilon > 0$, we also have $\bar{s}_i(c_i) - c_i \cdot \bar{q}_i(c_i) \geq \varepsilon \ \forall c_i < \hat{c}_i$ since the producer's expected profit is decreasing in the cost type, cf the proof of Proposition 1. In this case, the contract could be improved by reducing payments with ε for all $c_i \leq \hat{c}_i$. This would not affect the IC constraints.

$\forall i$. This is a property shared by many standard distributions, including the normal, the uniform, the chi-squared, the logistic and the exponential distribution.

From the integrand of $G^{IO}(q,s)$, we see that the processor would like to choose the maximal production level $\bar{q}_i(c_i) = q_i^U$ when $(p-c_i)f_i(c_i) - F_i(c_i) \geq 0$ and the minimal production level $\bar{q}_i(c_i) = 0$ when $(p-c_i)f_i(c_i) - F_i(c_i) < 0$. Since $(p-c_i)$ is decreasing in c_i and $F_i(c_i)/f_i(c_i)$ is weakly increasing in c_i, this does not conflict with the monotonicity of $\bar{q}_i(.)$. Hence, letting $\hat{c}_i = \sup\{c_i | (p-c_i)f_i(c_i) - F_i(c_i) \geq 0\}$, the optimal contracts under an investor owned monopsonist are

$$\bar{q}_i^{IO}(c_i) = \begin{cases} q_i^U & \text{for } c_i \leq \hat{c}_i \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

$$\bar{s}_i^{IO}(c_i) = \begin{cases} c_i \cdot q_i^U + \int_{c_i}^{\hat{c}_i} \bar{q}_i(\tilde{c}_i)d\tilde{c}_i = \hat{c}_i q_i^U & \text{for } c_i \leq \hat{c}_i \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

where $\hat{c}_i$ is defined as the unique solution to

$$(p - \hat{c}_i) = \frac{F_i(\hat{c}_i)}{f_i(\hat{c}_i)}$$

except for the boundary case where $(p-c_i^U)f_i(c_i^U) - F_i(c_i^U) > 0$ in which case we have $\hat{c}_i = c_i^U$.

As previously, the conclusions can be sharpened a bit further. Since the average production must be either minimal or maximal, so must all the specific production levels, i.e. we have $q_i^{IO}(c) = \bar{q}_i^{IO}(c_i) \quad \forall i, c$.

Above, we have characterized the best possible outcome for the monopsonist. One interpretation of the revelation game is that the monopsonist offers a menu of contracts from which the farmers' choose. Another is that he commits to a certain production and payment plan which depend on the cost reported by the farmers. It is interesting to note however that the outcome could also be implemented by a mechanism in which the processor simply offers farmer i a price equal to $\hat{c}_i$ per unit.

The optimal solution is generally ex post inefficient. When $\hat{c}_i$ is an inner solution, we have $\hat{c}_i = p - F_i(\hat{c}_i)/f_i(\hat{c}_i) < p$. This means that attractive production is forgone, namely when $c_i \in (\hat{c}_i, p)$. The monopsonist avoids trading with the higher costs farmers, not because they are too costly per se but to save on the information rents paid to low cost farmers. This loss of welfare is the result of the asymmetric information. Such losses are common in models involving negotiations under asymmetric information, cf e.g. Akerlof(1970), Vickrey(1961) and Chatterjee and Samuelson(1983). A model with much the same structure of the optimal solution as above is Antle and Eppen(1985).

An advantage of the formulations above is that they not only support the qualitative conclusion that investor owned processing leads to a welfare loss in many cases where the cooperative organization would solve the central planner's problem. They also allow us to measure the extent of the welfare loss and to identify circumstances where this is particularly important. The next section gives some examples.

6 Some Examples

To illustrate our results, let us assume that costs are independent and uniformly distributed, $c_i \sim U[\mu_i - \varepsilon_i, \mu_i + \varepsilon_i]$ where $\varepsilon_i \in [0, \mu]$ measures the uncertainty about farmer i's costs. Also, let the average net revenue product be $p \geq \mu_i - \varepsilon_i \ \forall i$. The potential social value from having farmer i produce - which is also the social value realized by the cooperative - is therefore

$$\int_{\mu_i-\varepsilon_i}^{\min\{\mu_i+\varepsilon_i,p\}} (p - c_i)\frac{1}{2\varepsilon_i}dc_i$$

It is straightforward to show that an IO processor will choose

$$\hat{c}_i = \min\{\mu_i + \varepsilon_i, \frac{p + \mu_i - \varepsilon_i}{2}\}$$

If for example $\mu_i = 1, \varepsilon_i = 1$ and $p = 2$, the IO processor offers $\hat{c}_i = 1$, i.e. he foregoes trading with half of the farmer types, the high costs types $c_i \in (1, 2]$, to reduce his payment to the low cost types $c_i \in [0, 1]$.

It follows that there will be no social loss from having a IO processor if and only if $\mu_i + \varepsilon_i \leq \frac{1}{2}(p + \mu_i - \varepsilon_i)$, i.e. if and only if

$$p - \mu_i \geq 3\varepsilon_i$$

Hence, the expected *profit margin* $p - \mu_i$ must exceed 3 times the *uncertainty* measure ε_i. (Of course, in the case $p \leq \mu_i - \varepsilon_i$ which we have excluded, there will also not be a loss since in this case production is not even attractive under the cooperative regime). Figure 2 below illustrates this.

A measure of the relative social loss from having an IO as opposed to an CO processor could be

$$RSL = \frac{\int_{\min\{\mu_i+\varepsilon_i,\frac{p+\mu_i-\varepsilon_i}{2}\}}^{\min\{\mu_i+\varepsilon_i,p\}}(p-c_i)\frac{1}{2\varepsilon_i}dc_i}{\int_{\mu_i-\varepsilon_i}^{\min\{\mu_i+\varepsilon_i,p\}}(p-c_i)\frac{1}{2\varepsilon_i}dc_i}$$

where the nominator is the social loss (from not producing when costs are high) in the IO regime and the denominator is the total social gain available (and realized by a cooperative). The relative social loss RSL as a function of p is depicted in Figure 1 below when $\mu_i = \varepsilon_i = 1$.

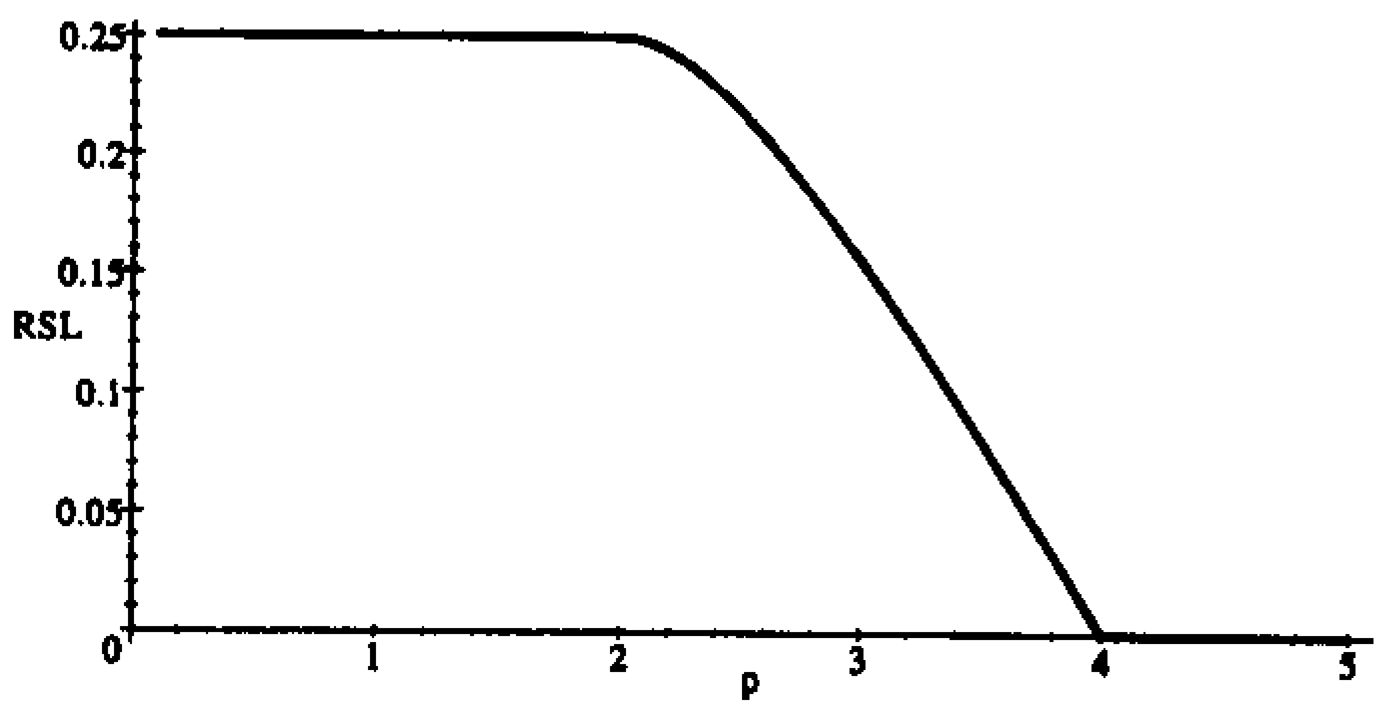

Fig 1.: Relative Social Loss from IO, $\mu_i = \varepsilon_i = 1$

A more detailed illustration of RSL is provided in Figure 2 where we assume

$\mu_i = 1$.

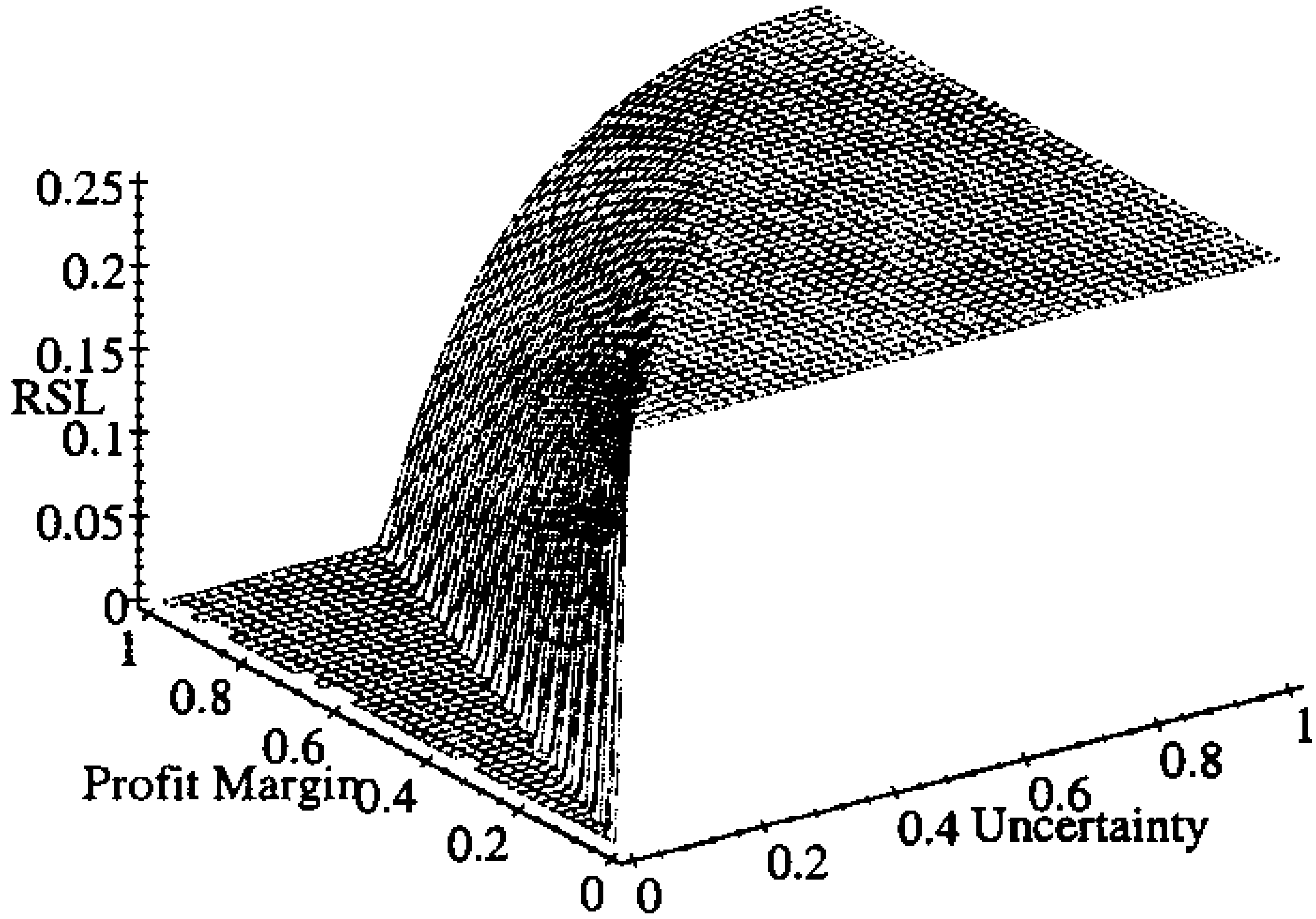

Fig. 2: Relative Social Loss from IO, $\mu_i = 1$

The production rationed away by the IO processor is the most expensive and therefore the socially least valuable. This explains why we, in the case $\mu_i = 1, \varepsilon_i = 1$ and $p = 2$, loose 50% of the productive cases but only (RSL=)25% of the value. It should be observed, however, that across farmers, we may not just ration away the least attractive cases. If for example $p = 1.5$ and we have two farmers, one with costs uniform on $[0, 1]$ and the other with costs fixed at 1, we would choose $\hat{c}_1 = 0.75$ and $\hat{c}_2 = 1$. Thus, all the cost levels we forego with farmer 1 is actually more profitable than the one we accept from farmer 2. We can conclude therefore that the inefficiency from private ownership may not just appear as lost production. It may also show itself as a misallocation of production rights where the least productive are allowed to produce more simply because their incentives are easier to control.

7 Extensions

The derived optimality of the cooperative organizational form rests on three essential assumptions, namely that types are independent, that the net average revenue product is constant, and that the income distribution does not matter.

The assumption that types are independent is necessary to prove Proposition 1. Specifically, (1) presumes independence. If the types are correlated, a social planner could undermine the informational advantage of the agents by comparing their messages. By paying most when an agent's message is likely given the messages of the other agents, the planner could reduce the payment to the agents. With perfectly correlated types, it would suffice to pay the true costs in all cases. Hence, with correlated costs, the cooperative solution is but one possibility to get the first best outcome. Indeed, with perfectly correlated costs, an IO processor would also generate the first best outcome.

One way to relax the independence assumption without changing our main results is to work with a refined set of IR constraints

$$s_i(c) - c_i \cdot q_i(c) \geq 0 \qquad \forall c, i$$

i.e. by assuming that the farmers must never end up with a negative cash-flow. The stronger IR constraints can be interpreted as limited liability constraints, safety first constraints, or as the usual participation constraints coupled with extreme risk aversion (prohibiting negative cash flows). Using the stronger IR constraints, and assuming that the joint distribution of types has support $C = \times_{i \in I} C_i$, we get basically the same propositions as above for the central planner and the cooperative - but we get it without using Proposition 1. This is not difficult to prove: Assume that $p < c_i^U$. To be socially optimal, we need farmer i to produce as long as $c_i \leq p$. The $c_i = p$ type of farmer i must therefore be paid at least p per unit and since all the more efficient types (by the full support condition) can imitate this type, they must all be paid at least p per unit. The budget balancing constraint now gives that they must be paid exactly p. Of course, there may still be room for some zero mean lotteries. An IO processor will still ration production since otherwise he will earn zero profit. Hence, in this case the socially optimal outcome is accomplished by a cooperative and - modula some zero mean lotteries - by a cooperative only.

The assumed constancy of the average net revenue product p is an assumption that the processor has no market power and that there are no scale economies in the processing (or less realistically, that these effects even out). Our conclusions are sensitive to this assumption. Relaxing it may destroy the cooperative's ability to give the first best production levels. Truly, first best production level may not be possible under any arrangement when p

depends on the aggregate production. However, the social planner's solution may be approximated better by an IO than by a CO processor in this case.

The assumption of a constant p is necessary to avoid the overproduction problem otherwise generated by a cooperative. In a cooperative, a member takes into account the price reduction that his production inflict on himself, but he does not internalize the loss imposed on the other members. This makes him overproduce. An IO processor on the other hand internalizes these losses. It follows that an IO processor may be socially superior as the internalization of the price reduction effect may more than outweigh the rationing due to asymmetric information. An added drawback of the cooperative when p decreases with production and costs are uncertain is the lack of coordination of production levels. By the processor's revenue function being concave, the socially optimal production levels will be coordinated such that producer i produces relatively more when farmer j has high costs and therefore produces less. This coordination is necessary even though costs types are independent - but it is not accomplished by a traditional cooperative.

The assumed irrelevance of the income distribution is obvious. The cooperative solution generates one distribution - favoring the most efficient farmers - and if this is not satisfactory, the cooperative solution may not be the optimal one.

In addition to the above qualitatively essential assumptions, we have introduced a more technical assumption about the class of cost functions. We have assumed that the farmers have linear costs and fixed capacity levels. One can argue that this is a relatively narrow class of cost functions. This is deliberate, however. Since we want to demonstrate that a cooperative is necessary to ensure the socially optimal production levels, a small class of function makes the result stronger. The other implication, i.e. that the cooperative suffices to give optimal production levels, would favor working with a large class. This way, however, is simpler and it holds for arbitrary classes of cost functions: Whatever his cost function $c_i(q_i)$, farmer i will choose the socially optimal production level, i.e. the q_i maximizing $pq_i - c(q_i)$ when processing is organized as a cooperative since in this case he is paid $p[\sum_{j\in I} q_j(c_j)]q_i/[\sum_{j\in I} q_j(c_j)] = pq_i$. We could have simplified the assumptions even further by using a discrete set of possible c_i values. A drawback of this however is that it require us to assume that p can take on the same values - a somewhat awkward assumption. Furthermore, using these assumptions we would not get the simple hazard rate results from Section 5. We could also have derived much the same results by claiming more traditional assumptions from the mechanism design literature, cf. e.g. Laffont and Tirole(1993). Specifically, we could have derived similar sufficiency and necessity results by assuming that the cost of farmer i's production is $C^i(q_i, \theta_i)$, where θ_i is the privately known productivity parameter, $\theta_i \in [\theta_i^L, \theta_i^U]$, that costs are increasing and convex, $\partial C^i/\partial q_i > 0$ and $\partial^2 C^i/\partial^2 q_i \geq 0$, that costs and marginal costs are increasing in types $\partial C^i/\partial\theta_i > 0$ and $\partial^2 C^i/\partial q_i \partial\theta_i > 0$ to ensure the so-called single crossing property, and more technically that $\partial^3 C^i/\ (\partial^2\theta_i \partial q_i) \geq 0$ and $\partial^3 C^i/(\partial^2 q_i \partial\theta_i) \geq 0$ to avoid mixed strategy and pooling equilibria, cf. Jensen(1998). We suggest that the assumptions we have inwoked are as realistic and certainly simpler to understand.

8 Conclusions

We have shown that with asymmetric information about farm level production costs, the only way to ensure socially optimal production levels may be to organize processing as a cooperative. This gives an information economic rationale for cooperatives. Specifically, we have shown that a cooperative is necessary when farmers' marginal production costs are independent, the net average revenue product from sales is constant, and the income distribution does not matter.

We have shown also that the relative advantage of cooperatives (compared to investor owned processors) is largest, when the cost uncertainties are large and when the profitability is limited, i.e. when the net marginal product is small compared to the primary production cost. In these cases the investor owned processor tends to ration away more social value to gain private value. Since the agricultural sector may have these properties, we suggest that our results may in part explain the apparent success of cooperatives among farmers.

In reality, the choice of organizational structure is not only determined by incentive costs. The resulting market behavior should be taken into account as well. Most likely, we would get different results if the market conditions are not - as assumed he - characterized by perfect competition. We leave the analysis of some such cases to future research.

Acknowledgments: This paper was written while Peter Bogetoft visited Department of Agricultural and Resource Economics, University of California at Davis and Peter M.F.Jensen visited University of California Berkeley. Financial support from The Danish Social Science Foundation is appreciated.

References

[1] Antle, R. and G.D.Eppen, *Capital Rationing and Organizational Slack in Capital Budgeting*, Management Science, 31, pp. 163-174, 1985.

[2] Akerlof, G. A. , *The Market for "Lemons": Quality Uncertainty and the Market Mechanism,* Quarterly Journal of Economics, 84, pp. 488-500, 1970.

[3] Chatterjee, K. and W.Samuelson, *Bargaining under Incomplete Information,* Operations Research, 31, pp. 835-851, 1983.

[4] Jensen, P.M.F., *An IO Approach to Cooperatives*, Working Paper, 1998.

[5] Laffont, J-J. and J. Tirole, *A Theory of Incentives in Procurement and Regulation*, MIT Press, 1993.

[6] Myerson, R., *Incentive Compatibility and the Bargaining Problem*, Econometrica, 47(1), pp. 61-74, 1979.

[7] Staatz, J.M., *A Theoretical Perspective on the Behavior of Farmers' Cooperatives*, Ph.D. dissertation, Michigan State University, 1984

[8] Tirole, J., *The Theory of Industrial Organization*, M.I.T. Press, 1988.

[9] Vickrey, W, *Counterspeculation, Auctions, and Competitive Sealed Tenders*, The Journal of Finance, 16, pp. 8-37, 1961.